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ENHANCED USE OF CLIPS
AT
THE LOS ALAMOS NATIONAL LABORATORY

by

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ABSTRACT

Early efforts in producing Expert Systems for engineering applications used a limited subset of CLIPS features. In this paper we discuss the implementation details of previous Expert Systems and of the current Expert System, which is used for training operators in the control of the Isotope Separation System.

INTRODUCTION

Three CLIPS-based Expert Systems¹ were developed to assist in solving engineering problems at the Los Alamos National Laboratory (LANL). These systems were justified by The Laboratory's need to save corporate knowledge that might be lost by personnel attrition and by the requirement to transfer the technology to industry. Two of the systems were advisors designed to aid in the selection of the "best" equation of state models for process design², and to screen enhanced oil recovery methods³. These advisors were not used for control nor did they include explanation facilities. The third Expert System⁴ to assist in the production of silicon carbide whiskers is similar in function to that of our current system. As can be seen in Fig. 1, whisker growth is a complex process. Although whisker growth is difficult, if not impossible, to model mathematically, "excellent" whiskers can be grown by a human expert.

The LANL Materials Science and Technology Group MST-3 is responsible for research and development of systems and equipment for the handling and processing tritium, the heavy radioactive isotope of hydrogen. The group runs the Tritium Systems Test Assembly (TSTA) in which equipment and processes are tested for use with a fusion reactor fuel cycle.

The Isotope Separation System (ISS) shown schematically in Fig. 2, is one of the systems housed in the TSTA. It utilizes cryogenic distillation columns to separate hydrogen isotopes (protium, deuterium and tritium) into pure component streams. Controllers, which are conventional and of 10 year-old technology, require frequent manual adjustments of setpoints to accommodate the non-steady state nature of the ISS. A large amount of data must be monitored by operating personnel. System interactions are complex, making optimum operation difficult to attain.

The operation and control of the system is an art that is understood by only a few technical personnel who have long experience with the system. Even these experienced personnel have problems assimilating and reconciling variables in a timely manner. It was decided that an Expert System should be developed to collect and document the knowledge of the few experts in the ISS operation. This system could then be used to assist the technicians who normally operate the system and to train new personnel.

The success of earlier Expert Systems was largely instrumental in considering the use of an expert advisor for this system. The Whisker Production Advisor is currently being transferred to industry.

DESIGN CONSIDERATIONS

Whisker Production Advisor

We felt that any usable expert system should be executable with an inexpensive shell and an easily available computer. The PC version of CLIPS was chosen for this task. The search trees associated with production run setup and run control had five levels, so they required a good search algorithm in order to obtain a reasonable response. CLIPS's RETTE algorithm was adequate for the task.

ISS Advisor

Since the resident experts were approaching retirement age, the knowledge base constructed should be easy to maintain and should be as complete as possible. The operators had considerable experience in seeing the data appear on graphic devices and, although an easy interface was not top priority, we soon learned that it made acceptance of this tool much easier. Available hardware was limited to the IBM AT class of personal computers. The size of program developed should fit in available memory (<640 kbytes). Finally, the program should be easy to maintain.

THE PROGRAMS

The Whisker Advisor

Figure 3 shows the organization of the whisker advisor. The two parts, run setup and control system, were developed separately, and each was embedded in the CLIPS shell. The operator interacts with the system through the computer keyboard and screen. Figure 4 illustrates a partial sample dialog for a hypothetical run.

The ISS Advisor

The structure and information flow of the ISS advisor is shown in Fig. 5. The main program is written in ANSI C. It provides the user interface, whether the interface is textual or graphics, obtains the initial conditions, and asserts the facts obtained in the main program, to the embedded CLIPS rules. The main program retrieves the advice generated by CLIPS and displays it to the operator.

The program begins by giving the user a brief description of the program's purpose. The CLIPS environment is then initialized and rules from the file ISS.CLP are loaded into the system. The program now has the "brain" necessary to make decisions based on data to be input later. The user then enters the main loop of the program.

The main loop initially gives the user a list of possible options pertaining to the type of problem to be solved. Depending on the users answer, the program searches for data pertaining to the specified problem. The user is also permitted to input fresh data via Option 6. The program loads in data and the user is permitted to make adjustments. The user is also permitted to input "no data available" for any combination of data cells. Figure 6, shows the data for a default scenario, the cursor is positioned at the data cell to be changed and new data can replace that shown. Compare this with the elicitation scheme shown in Fig. 4.

Once data is available, it is asserted to the rule base (brain) and the appropriate action is determined based on the given information. Figure 7 illustrates the types of rules created from the asserted information (could be specified or measured). If blanks are input into the data, the value "99999" is asserted to the rule base. This number is used to numerically mark (becomes a flag) to indicate "no data available." Any rule finding "99999" as data will not fire. As rules fire, a queue is filled containing text or display information that is sent back to the main C driver program from the rulebase, placed on a stack, and sorted. The text statements or display information is then shown as suggestions to the user. This completes a pass through the main loop of the program; however, the user is permitted to cycle through the loop as many times

as requested with new and/or reused data.

Three versions of the ISS advisor exist: (1) ISS.EXE (a color text version); (2) ISSL.EXE (a black and white version for lap-top personal computers); and (3) ISSIS.EXE (a graphics version which has proven to be the most popular of the three versions).

Figure 8 is a sample screen produced by the advisor. The amount of information presented is much greater and more compact than simple textual dialog.

CONCLUSIONS

A friendlier interface was obtained by embedding CLIPS inside a main C program than for our earlier versions of Expert Systems. Preliminary versions of the ISS advisor have shown that the memory limitation has been avoided by the careful use of files for the verbose advice indexed by the "fired" rules and also by placing the initial conditions for various scenarios in data files. The use of templates has helped in the documentation of the rules and has generally improved the readability of the code.

It would have been helpful if rounded floating point data were available to be passed back in string form to the main program. CLIPS version 5.0 was received too late for use in this project.

Although testing the advisor against the actual operation of the Isotope Separation System has been limited, the use of graphics has greatly enhanced the acceptance of the advisor.

REFERENCES

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2. W. J. Parkinson, G. F. Luger, and R. E. Bretz, "Using PC-Based Shells to Write an Expert Assistant for Use with the ASPEN Computer Code," Paper presented at the AIChE Annual Meeting, Session on Applications of Artificial Intelligence in Chemical Engineering, April 2-6, 1989, Houston, Texas.

3. W. J. Parkinson, G. F. Luger, R. E. Bretz, and, J. J. Osowski, "An Expert System for Screening Enhanced Oil Recovery Methods," Paper presented at The 1990 Summer National Meeting of The American Institute of Chemical Engineers, San Diego, California, August 19-22, 1990.
4. W. J. Parkinson, P. D. Shalek, E. J. Peterson, and G. F. Luger, "Designing an Expert System for the Production of Silicon Carbide Whiskers," Paper presented at the TMS Annual Meeting, Symposium--Expert System Applications in Materials Processing & Manufacturing, February 19-22, 1990, Anaheim, California.

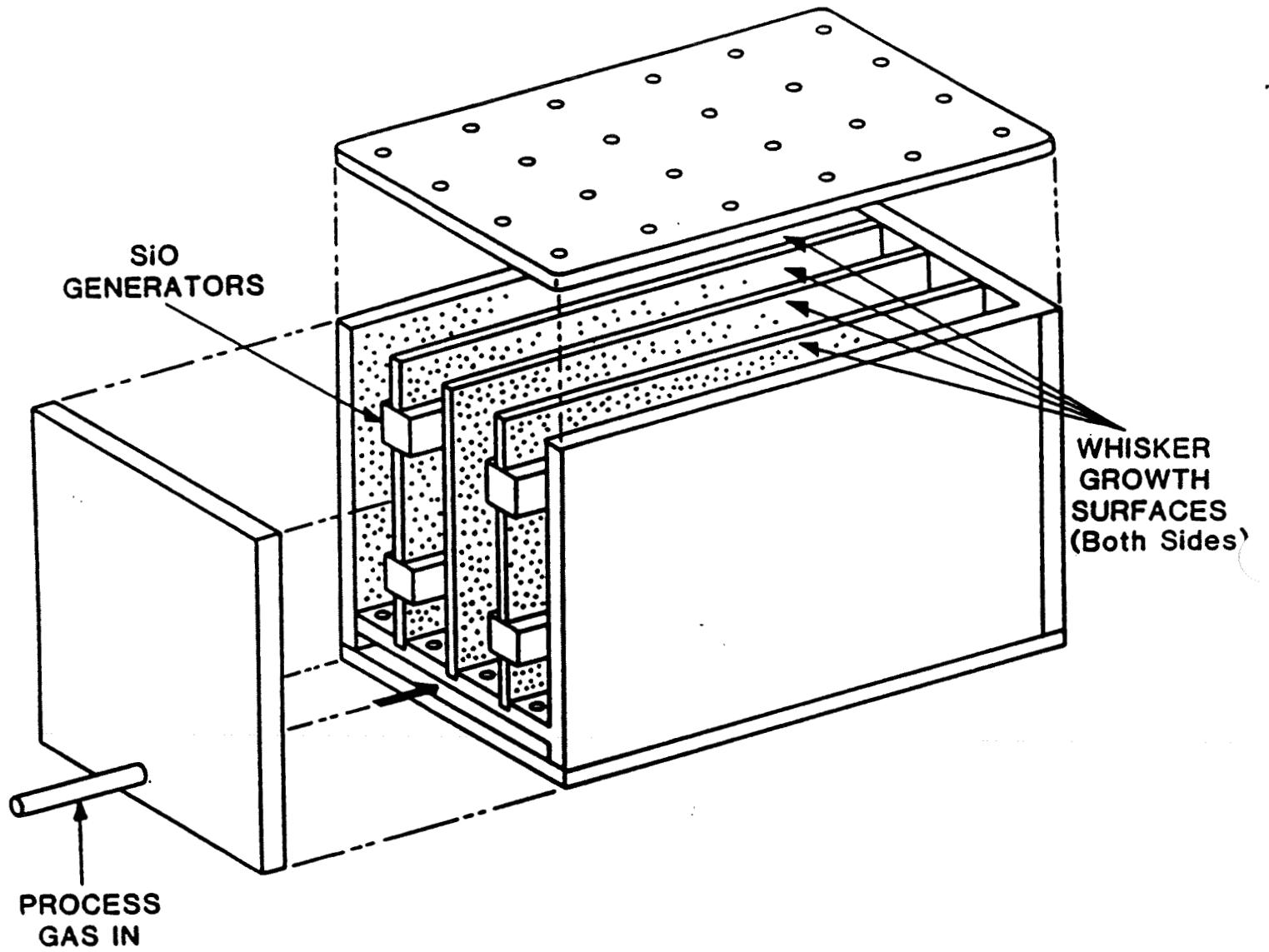


Figure 1. Los Alamos Silicon Carbide Whisker Production Reactor.

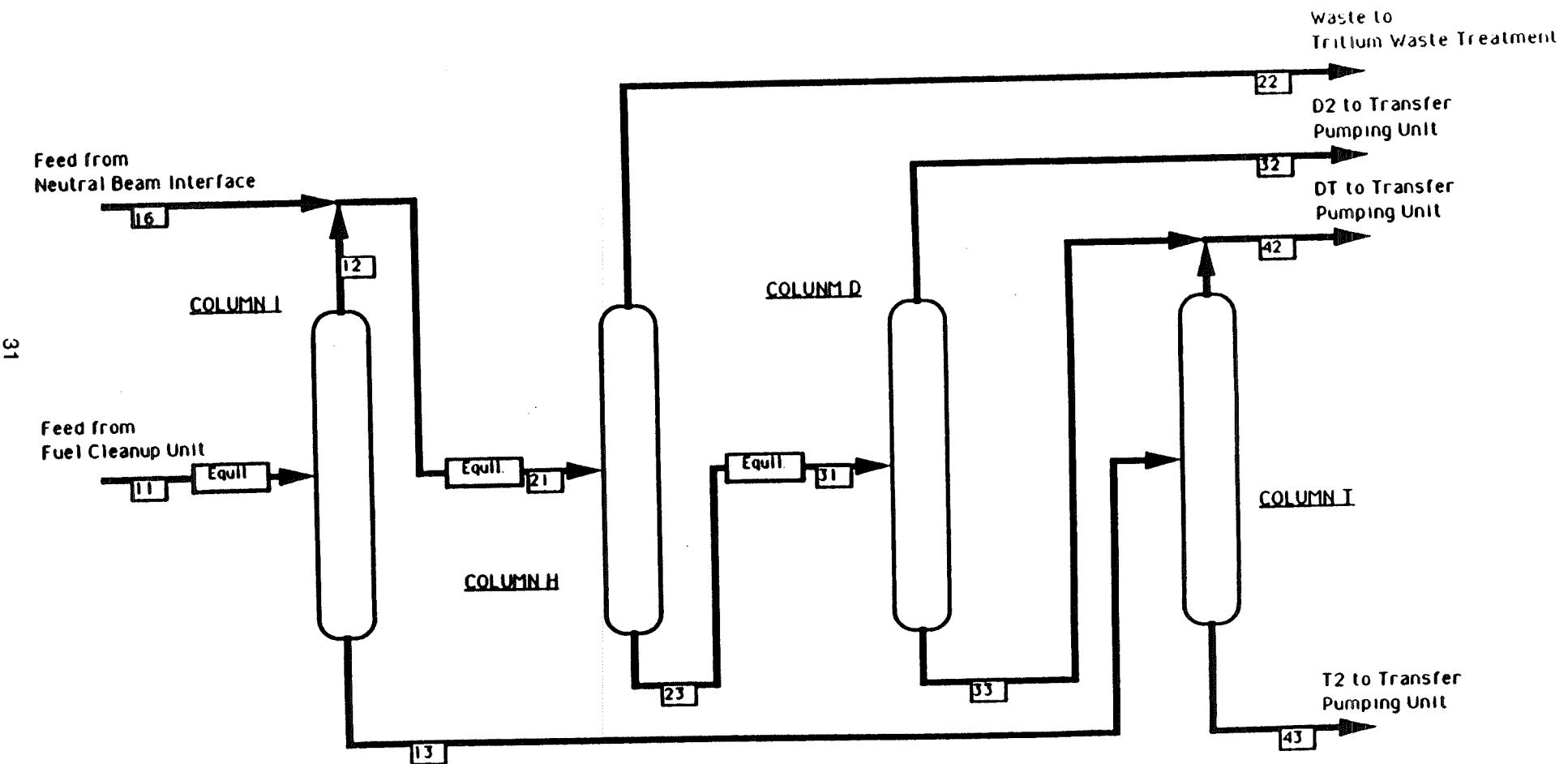


Figure 2. Isotope Separation System Schematic.

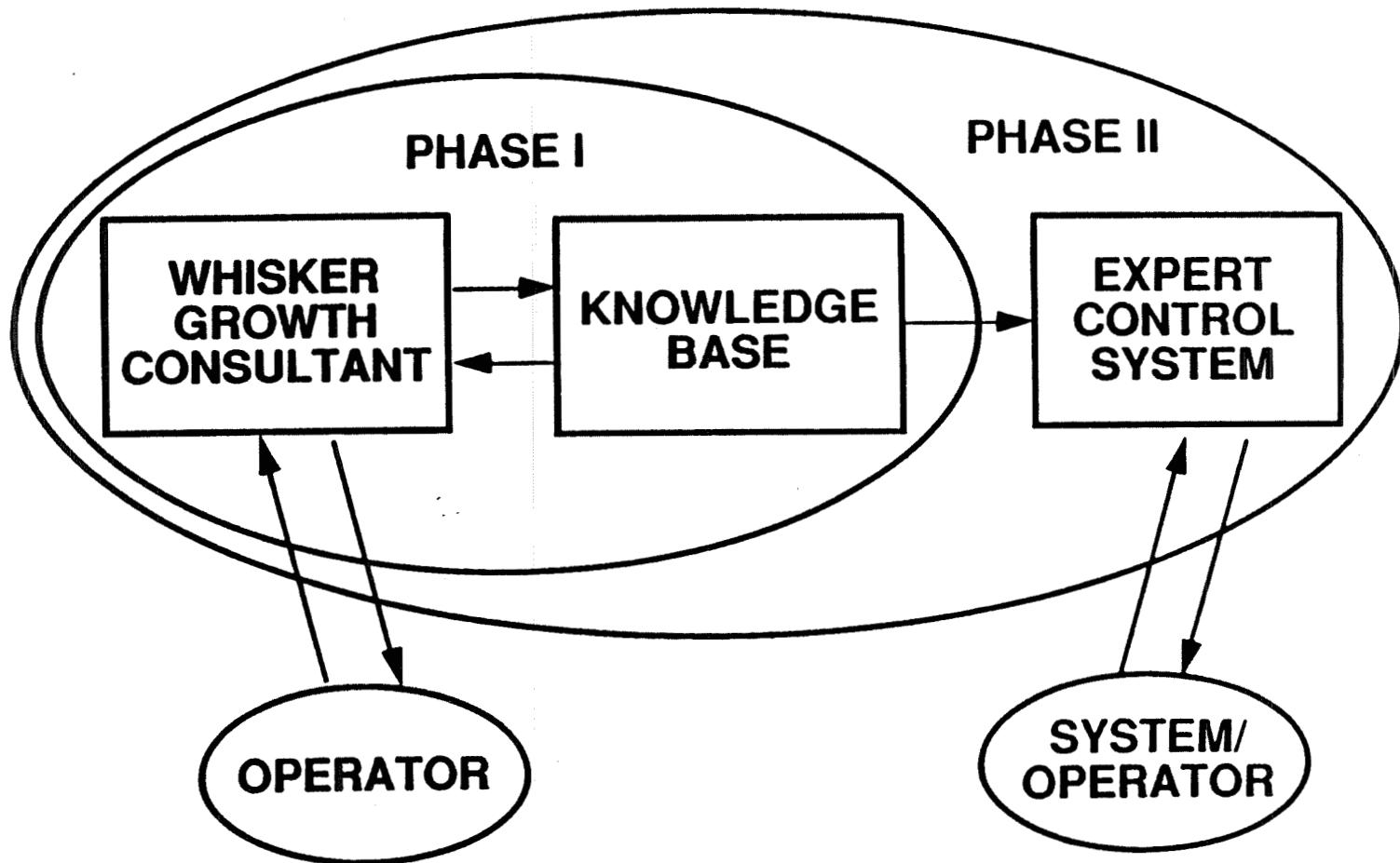


Figure 3. Whiskers Expert System.

What is the desired average whisker length ?
(in inches 0. to 3.5)

3.0

We recommend reactor type B, which will you use ?
(A or B)

B

What is the desired average whisker diameter ?
(in microns, 0 to 12)

10

We recommend the manganese based catalyst, which
one will you choose ? (manganese or iron)

manganese

.

.

We recommend that you vary the CO concentration according to
time-concentration profile A. What profile will you use ?

(A, B, C, or D)

A

Figure 4. Sample Dialog for The Whiskers Advisor.

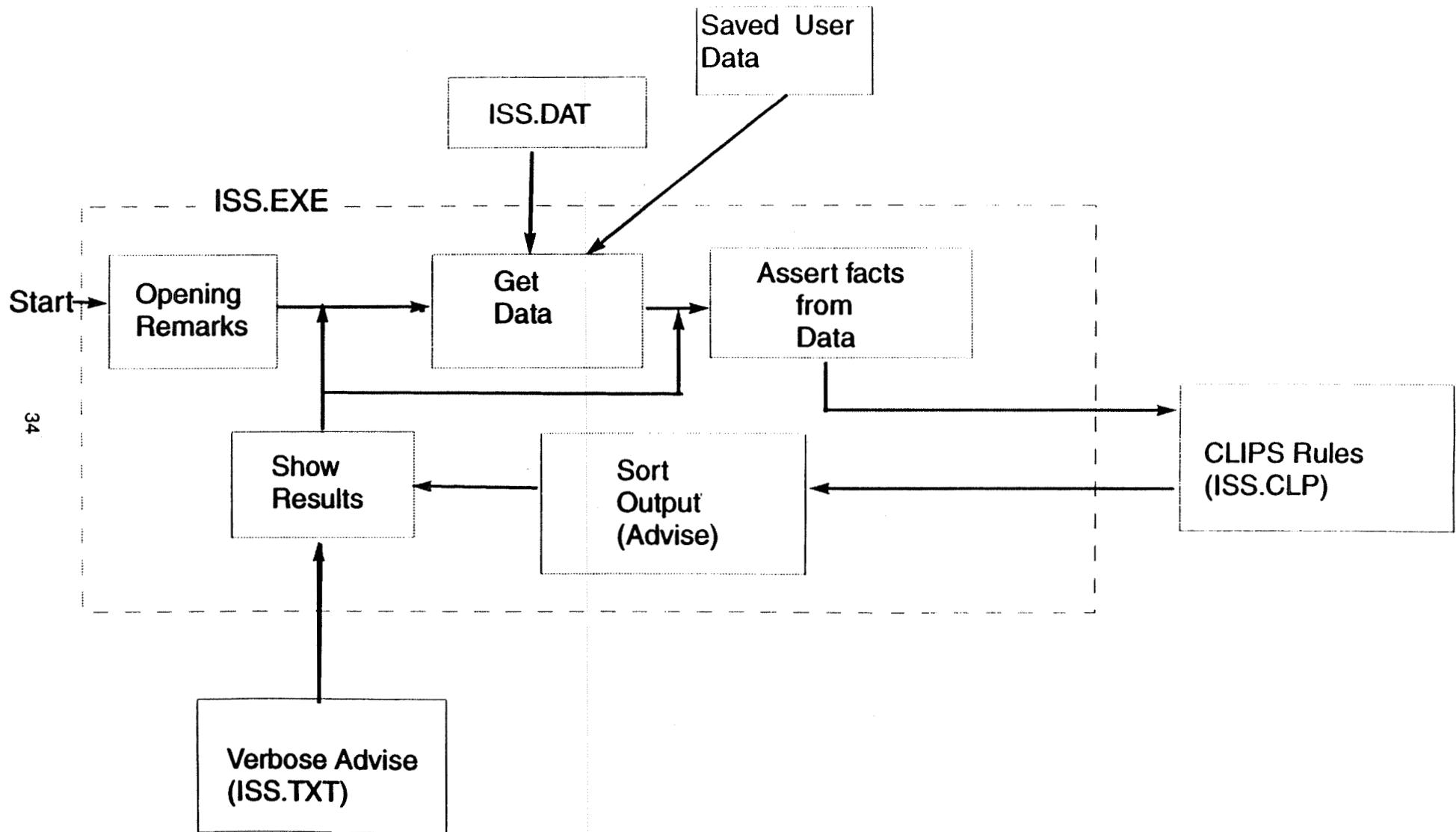


Figure 5. ISS Advisor Structure.

ISOTOPE SEPARATION SYSTEM EDITOR

	I	H	D	T
Pressure (torr) :	700	600	500	400
Diff. Pressure (mm) :	12	12	12	12
Flow-CL(n)C (l/min) :	8	4	2	1
Reboiler level (cm) :	15	15	15	15
Reboiler Set (cm) :	9	9	9	9
M-CLIC Comp (n.f. He H2 DT T2) :	.2	.2	.2	.2
M-CLHC Comp (n.f. D2 DT) :	.5	.4		
M-CLDC Comp (n.f. D2) :	.9			
M-CLTC Comp (n.f. T2) :	.9			
R-CLHA Radiation (ci/m^3) :	.01			
F-D2IN NBI flow (l/min.) :	5			

Would you like to change these settings (y or n) ?

Figure 6. ISS Input Editor Display Screen.

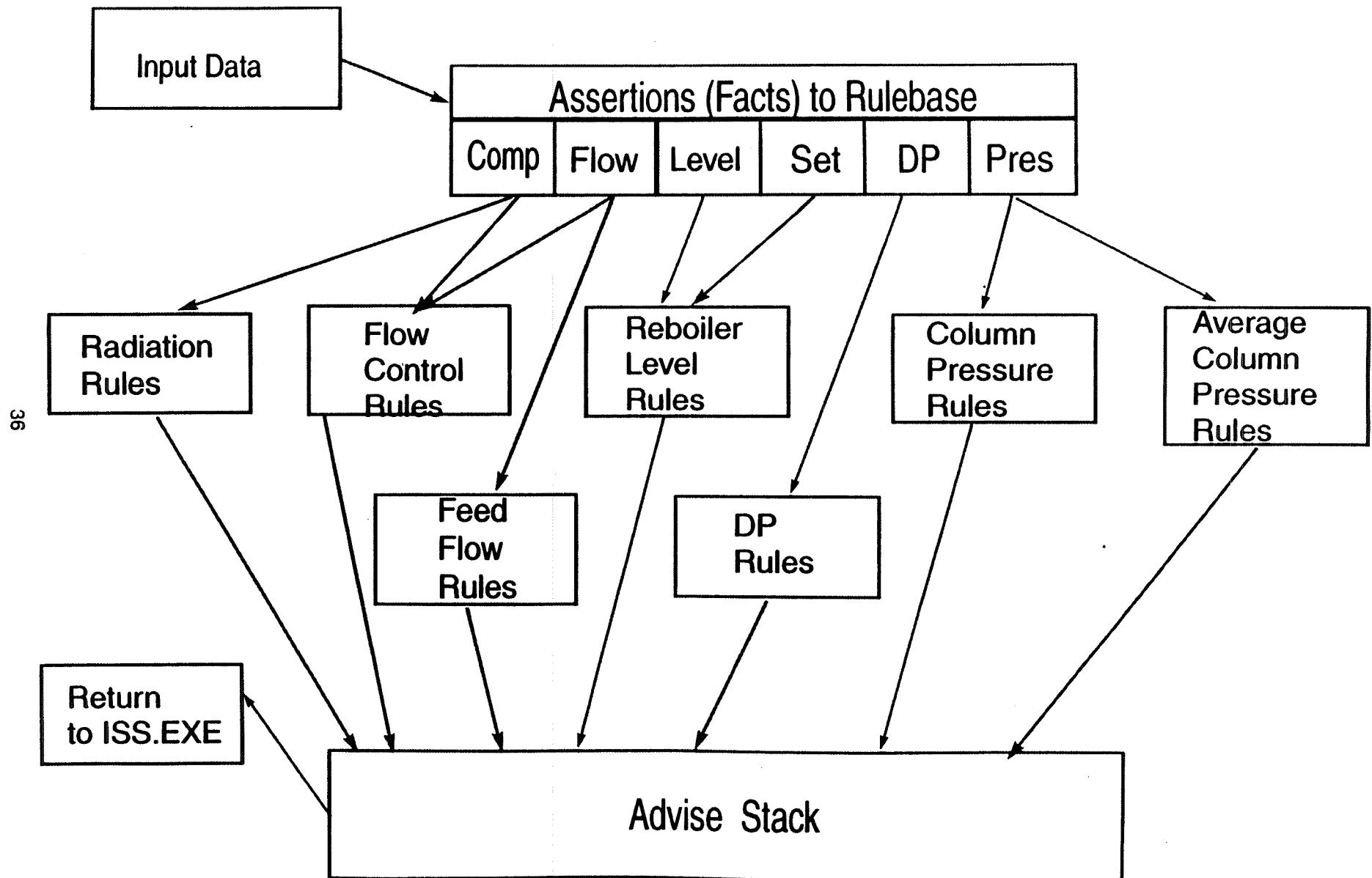


Figure 7. ISS Rulebase.

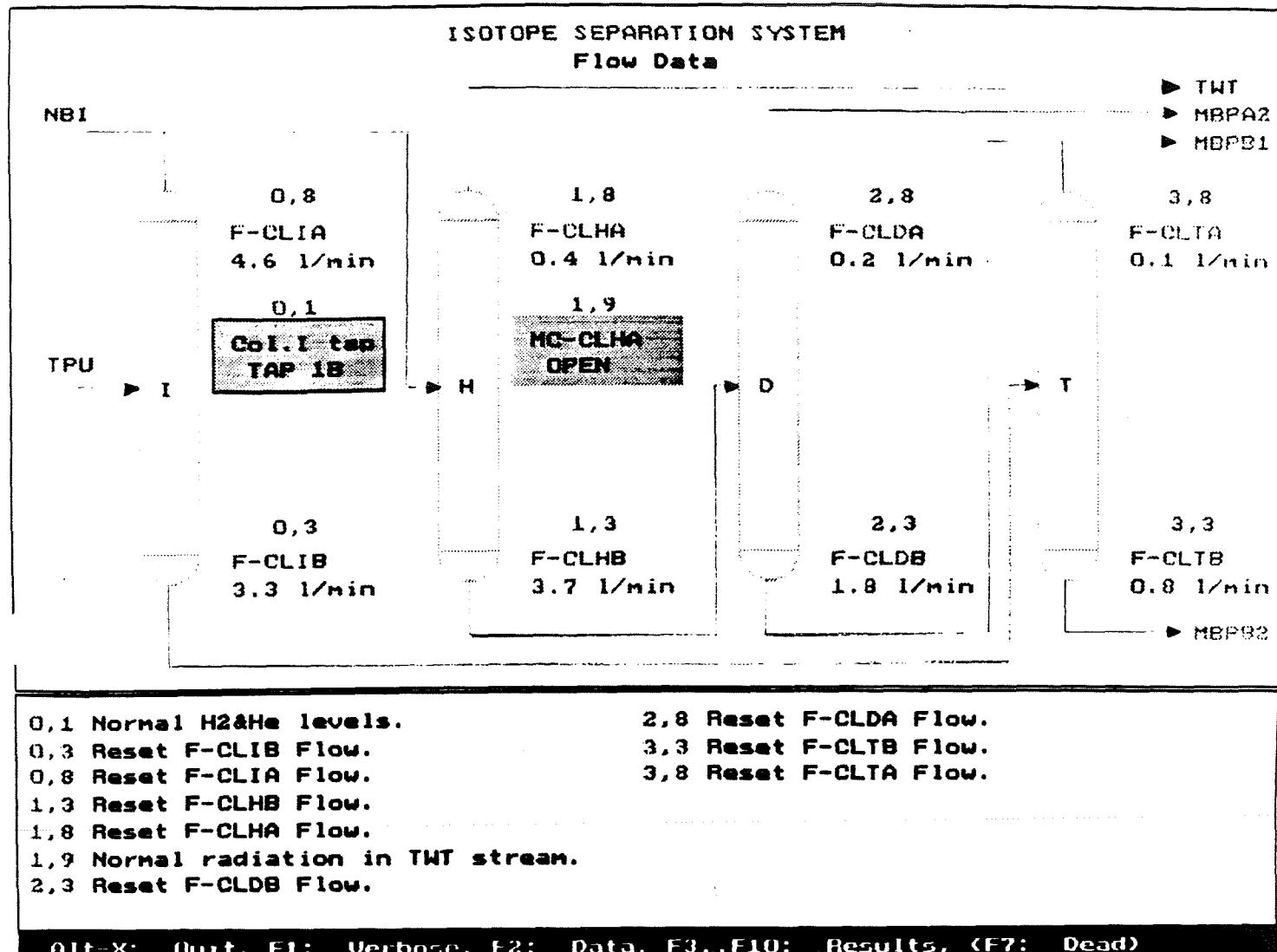


Figure 8. ISS Sample Output Graphics Display.

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